

# PATENT SPECIFICATION

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## DRAWINGS ATTACHED

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## (54) IMPROVEMENTS IN OR RELATING TO GUNS

(71) We, **ETHER ENGINEERING LIMITED**, a British company, of Park Avenue, Bushey, Hertfordshire, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to guns. More particularly, this invention relates to a gun which is suitable for use in a variety of tests, such as impact tests in which a projectile is fired into a target, free flight tests in which a projectile is fired into free flight, and acceleration tests in which an article is subjected to a relatively prolonged acceleration.

According to the present invention there is provided a gun comprising a tubular barrel of which the ends are initially sealed by respective disruptable closure members, means for withdrawing air from said barrel and means for disrupting one of said closure members whereby a projectile member fitting slidably within said barrel adjacent said one closure member is accelerated towards and discharged from the other end of said barrel through the other of said closure members, wherein said disrupting means comprises an annular ring of blades.

In a preferred embodiment of the invention the ends of the barrel are provided with radially outwardly extending peripheral flanges against each of which a thin membrane of synthetic plastics material is pressed by an annular ring urged there-against. Each flange may be provided with an annular groove containing an O-ring seal and each annular ring may be urged against the associated membrane by hydraulic pressure to obtain exactly reproducible conditions of rupture.

The annular array of blades is preferably arranged to engage a peripheral zone of the membrane and the array may be

carried in a ring mounted on a surrounding collar by mutually engaged radial pins and helical slots. Rotational movement of the ring reduced by an actuator thus results in axial movement of the blades to sever the membrane.

The true projectile may be carried in a sabot, in which case a separator permitting free passage of the true projectile but arresting the sabot will be provided.

Features and advantages of the invention will appear from the following description of an embodiment thereof, given by way of example with reference to the accompanying drawings, in which:—

Figure 1 is a diagrammatic sectional view of a gun in accordance with the invention;

Figure 2 is a partial plan of the gun of Figure 1;

Figure 3 is a section end elevation taken along the line 3-3 of Figure 1;

Figure 4 is a partial sectional elevation illustrating a modification of the gun shown in Figure 1;

Figure 5 is a diagram illustrating one use of the gun;

Figure 6 is a diagram showing a projectile disposed in a sabot in the breech of the gun, ready for firing;

Figure 7 is a diagram showing another projectile; and

Figure 8 is a diagram illustrating a magnetic tape-recorder device which may be used in a projectile.

The gun shown in Figure 1 is operated by vacuum. The gun comprises a barrel which may be connected to a vacuum pump, the muzzle and breech of the barrel being sealed by diaphragms. In use, the projectile is placed in the breech, and the muzzle and breech are sealed by the diaphragms. The barrel is then evacuated. The breech diaphragm is then punctured and air flows in from the atmosphere. This applies a pressure to the base of the projectile, which is thus

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accelerated down the barrel to puncture the muzzle diaphragm and emerge from the barrel. If the projectile does not conform to the cross-section of the barrel it may be placed in a sabot, and it may be desired to separate the sabot from the projectile after firing. Separation is partly achieved by the aerodynamic pressure on the sabot as it emerges with the projectile from the muzzle, but a baffle may also be provided to catch the sabot, while permitting the projectile to continue.

The gun is particularly simple in construction and operation, but its operation is accurately reproducible. High muzzle velocities can readily be achieved without applying explosive accelerations to the projectile.

One particular advantage of the gun is that there is little disturbance of the air at the muzzle end of the gun caused by the propellant, since the propellant is air at atmospheric pressure and there is vacuum ahead of the projectile.

Accordingly, the gun finds a particular use where it is desired to make impact tests on a liquid, since the muzzle of the gun can be placed quite close to the liquid target, without disturbing the surface of the liquid before the arrival of the projectile.

Another particular use of the gun is in acceleration tests, since the acceleration of the projectile along the barrel is relatively prolonged. Accelerations several hundred times the acceleration due to gravity, that is to say of several hundred thousand centimetres per second<sup>2</sup> can readily be achieved for periods up to and exceeding 100 milliseconds. Alternatively, the projectile can be fired into a yielding target to give a prolonged deceleration which can be a predetermined function of time.

Referring now to Figures 1, 2 and 3 the gun comprises a barrel 10 which may conveniently be made of a resin-bonded paper material, although fibre glass or metal barrels are also satisfactory in some circumstances. The barrel 10 is provided with a flange 11 at the breech end, and a similar flange 12 at the muzzle end, these flanges being provided with annular grooves 13, 14 containing 'O'-ring seals 13a and 14a. A pipe union 15 is provided by which the interior of the barrel can be connected by way of a conduit 49 to a vacuum pump 50. An annular clamp member 16 is provided at the muzzle end of the barrel, for clamping against the 'O'-ring seal 14a a circular diaphragm 17 of thin and flexible sheet material, such as "Melinex", (Registered Trade Mark), which may have a thickness of 0.002 inches. The diaphragm 17 is sufficiently strong to withstand atmospheric pressure when the barrel is evacuated, but equally is sufficiently weak to burst readily

on impact of the projectile when the gun is fired. A similar diaphragm 18 and clamp-member 19 is provided at the breech of the gun. The clamping members 16 and 19 may be tightened on to the barrel by pins such as 16a, which are urged against the clamping ring by hydraulic pressure, applied by hydraulic cylinders such as 16b, so as to obtain a reproducible pressure on the "O"-ring seals 13 and 14. Alternatively, the clamp members 16 and 19 may be arranged to be clamped by screw clamps such as 16c or to screw on to the muzzle and breech as shown in Figure 4, where it will be seen that clamp members 16 and 19 are provided with annular, internally screw-threaded flanges 16d, 19a which engage with external screw threads formed on barrel flanges 12 and 11 respectively.

The clamping member 19 is provided with a collar 20 which supports the breech mechanism. The breech mechanism is arranged to puncture the breech diaphragm 18 when the gun is to be fired. In the embodiment shown in Figure 1, the breech mechanism comprises a ring 21 carrying at its periphery a ring of blades 22. The ring 21 is provided with a plurality of guide pins such as 23, which cooperate with inclined slots such as 24 formed in the collar 20 to guide the movement of the ring 21. The serrated edges formed by the blades 22 are inclined in the opposite sense to the slot 23. A solenoid actuator 25 (Fig. 3) is provided which is mechanically coupled to ring 21 by means of a link 25a so that when the solenoid is energized, ring 21 is sharply rotated, so as to drive the blades 22 into the diaphragm 18 at the periphery of the bore of the barrel 10. The entire diaphragm is thus cut out sharply and quickly, permitting air to flow smoothly into the evacuated barrel 10.

In the embodiment shown in Figure 1, the projectile 26 which is to be fired is smaller than the bore of the barrel 10, and is supported in a sabot indicated at 27. The sabot acts as a piston of which the head is a close fit in the bore of the barrel 10, and which has an annular skirt 28 projecting forwardly from the head of the sabot, the forward end of the skirt being sharpened, so as to sever the diaphragm 17 adjacent its outer periphery. The sabot 27 is conveniently made from a low-density material such as expanded polyurethane, although other expanded plastics materials, or wooden materials, could be used. The expanded polyurethane is formed with a tough skin at its surface, which gives the body sufficient structural rigidity. However, the material is not sufficiently strong to transmit the acceleration force to the projectile directly, and a rigid load distributing plate 29 is positioned behind the projectile 26

and the inner surface of the base of the sabot. Radial supports 30 and 31 are provided to hold the projectile against lateral movement.

5 To separate the material of the sabot 27 from the projectile 26 when the gun is fired, a separator 32 is preferably provided outside the muzzle of the gun. This separator comprises a baffle plate 33, having an aperture 34 coaxial with the barrel 10. A tube 10 35 is mounted on the muzzle side of the baffle 33. When the projectile and sabot emerge from the muzzle of the gun, the sabot is usually retarded by the air pressure more rapidly than is the projectile, and 15 separation begins. In any case, the projectile 26 passes into and through the tube 35, while the skirt 28 of the sabot passes outside the tube. The projectile is thus free to carry on unimpeded, while the 20 skirt 28 disintegrates against the baffle 33, and the plate 29 and base of the sabot are stopped by the tube 35. A certain amount of material from the sabot may pass down the inside of the tube 35, but this will 25 usually have been delayed considerably by the aerodynamic pressure, and by the disintegration of the sabot, and will follow some distance after the projectile.

30 The speed of the projectile may be measured by measuring the time taken for the projectile to traverse a known distance. For instance, pulses may be generated by the projectile breaking two wires in 35 succession, which are separated by a known distance in the direction of motion of the projectile. In a preferred method, two members of soft iron material are secured to the projectile spaced apart in the direction 40 of its motion, and the passage of these two members is sensed by a stationary magnetic pick-up, which may for instance comprise a magnetic circuit energised by a coil, and including an air gap disposed beside the 45 path of movement of the two soft iron members. The two electrical pulses derived may be displayed on an oscilloscope, so that the spacing of the pulses as seen on the cathode ray tube of the oscilloscope is 50 a measure of the velocity of the projectile. Alternatively, the two pulses may be used to start and stop a counter fed with clock pulses recurrent at a known rate.

When acceleration tests are to be conducted, it is often desirable not to destroy 55 or mutilate the projectile fired. To prevent this, the projectile may be fired into a mass of soft material, such as cotton waste. Preferably, however, as shown in Figure 5, 60 the projectile is fired into a tube 36 which is closed at one end, which has a flange used to clamp the closure member 17 to a flange on the gun, and which contains air at atmospheric pressure. As the projectile 65 enters the tube 36, it compresses the air

in the tube in front of it, and a relatively gradual deceleration is applied to the projectile. To prevent the projectile from being returned back down the tube 36 by the air pressure built up in the tube, a restricted 70 outlet 37 is provided from the closed end of the tube 36. If the projectile is mounted in a sabot, it is necessary to secure the projectile very securely to the sabot, and the sabot must be made sufficiently strong to 75 withstand the sudden reversal of acceleration. The sabot 27 described in relation to Figure 1 would not be suitable. Alternatively tube 36 could be made with an internal diameter suited to that of the projectile. 80

The dimensions of the projectile or sabot are fairly critical. However, a certain amount of clearance of the projectile from the bore of the barrel 10 can readily be 85 tolerated, and in fact a clearance of about one tenth of an inch is preferred for a sabot with a diameter of 10 inches. In this connection, leakage of a small amount of air round the side of the projectile may act to lubricate the motion of the projectile. In a typical case, the length of the barrel 10 was 20 ft., its diameter was 10.2", the projectile mounted in the sabot 27 weighed 3 lbs., and the barrel 10 was evacuated to 95 approximately 1/10 millimetre of mercury. The acceleration achieved was approximately 400 times the acceleration due to gravity, and the muzzle velocity was approximately 600 ft. per second. 100

It is possible to vary the acceleration and muzzle velocity by varying the weight of the projectile, by varying the initial position of the projectile in the barrel 10, by varying the length or diameter of the barrel 105 10, or by varying the pressure of air remaining in the barrel 10 before firing. This last method may not be desirable, since retardation of the sabot may occur before the diaphragm bursts, and the projectile may 110 be projected through the diaphragm ahead of the sabot.

It is often required to record signals generated within the projectile in motion, such signals for instance being indicative 115 of the time of occurrence of an event, such as the time relative to first touch when an impact device has effectively operated. The signals may be transmitted to a stationary recorder either by means of a trailing wire, 120 or by a radio link. Figure 6 shows an example of the way in which a trailing wire system can be arranged in a gun according to the invention. Before the gun is fired, a coil 38 of light flexible wire, preferably a 125 coaxial cable, is positioned in the breech of the gun behind the sabot 27, the stationary end 38a of the cable passing out through the side of the gun barrel to a suitable recorder 51. The cable extends into 130

the sabot, and a further small coil 39 is formed in the sabot behind the projectile. The inner end of the cable is secured to the projectile, and is connected to the relevant device under test. The total length of cable in the coils 38 and 39 must be greater than the total distance to be travelled by the projectile.

As the projectile accelerates down the gun barrel, the cable is pulled after it, and this sets a limit to the length of gun barrel with which the trailing wire method can be employed. The acceleration of the length of cable to follow the projectile 26 down the gun barrel puts the cable under a heavy tension, and the longer and heavier the cable is, the greater is this tension. For this, and other reasons, it is sometimes preferred, as shown in Figure 7, to use a radio link between the device in the projectile and a stationary recorder. The projectile then includes a small frequency modulation transmitter, coupled to an aerial 40 which conveniently projects out of the back of the projectile. Signals transmitted from the projectile may be picked up by an appropriately positioned aerial but, particularly where the projectile is fired at a target which reflects radio waves, the limiter response of the receiver should be fast-acting, since rapid signal level fluctuations occur due to the movement of the projectile, and of its radio image reflected in the target. The transmitter in the projectile is conveniently a thin film construction encapsulated in a moulded plastics material, so that the transmitter can survive the high acceleration stresses imposed in use.

Alternatively, instead of transmitting the information to a stationary recorder, a miniature tape-recorder may be incorporated in the projectile. Figure 8 illustrates such a device. In this device, a moulded plastics base member 41 is provided with a pair of cavities 42 and 43 which receive and closely support a pair of spools 42a, 43a carrying a length of magnetic tape. Two magnetic recording heads 44 and 45 are provided beside the tape path, to provide four-track recordings on the magnetic tape. The tape is driven past the spools by a simple spring drive whose release is controlled by a star and pallet device, the drive being applied to the spindle of one of the tape spools. Where it is required to record the relative times of occurrence of one or more events, a simple plastics encapsulated oscillator can generate a reference frequency signal, which is switched on and off in response to the events to be recorded. Although the movement of the tape is not exactly uniform, or exactly known, the number of cycles of the reference signal recorded during the time which is to be measured can be counted to give an accurate measure

of the time. The tape-recorder is virtually destroyed after one impact, but the nature of the base member 41 which closely supports the tape prevents the tape itself from being destroyed, and the simple construction of the device makes it readily expendible. It will be apparent that this tape recorder device also has a number of applications apart from its use in conjunction with the vacuum gun.

Figures 6 and 7 show a suitable design for the projectile for an impact test, in which the device to be tested is shown at 46, being supported from the main body 47 of the projectile by a frangible structure 48. Ancillary equipment, such as the transmitter of the device of Figure 7 is mounted in the main body 47 of the projectile, so as to continue operating while the device 46 strikes the target. The structure 48 collapses when the device 46 strikes the target, so that it is only subsequently that a substantial impact force is applied to the main body of the projectile 47.

Where it is desired to measure the time of operation of an impact device relative to the first touch of the projectile, the electrical signal given by the impact device can readily be recorded. The time of first touch can be recorded with the trailing wire method by earthing the projectile, and applying a high voltage to the target (if this is water, the high voltage may be applied by an electrode immersed near the target point); when the projectile touches the target, a high voltage pulse is applied to the earth wire of the cable, which can be used to mark the time of first touch.

Again, the time between the two events, such as between first touch and operation of the impact device may be measured by starting and stopping a counter to which clock pulses are applied, or by applying the pulses to an oscilloscope and measuring the spacing of the pulses on the cathode ray tube.

#### WHAT WE CLAIM IS:—

1. A gun comprising a tubular barrel of which the ends are initially sealed by respective disruptable closure members, means for withdrawing air from said barrel and means for disrupting one of said closure members whereby a projectile member fitting slidably within said barrel adjacent said one closure member is accelerated towards and discharged from the other end of said barrel through the other of said closure members, wherein said disrupting means comprises an annular ring of blades.

2. A gun in accordance with claim 1 wherein said disruptable closure members are thin membranes of synthetic plastics material.

3. A gun in accordance with claim 1 or claim 2 wherein said barrel is provided at an end thereof with a radially outwardly extending peripheral flange to which said closure member is sealed.
4. A gun in accordance with claim 3 wherein said flange contains an annular groove in which is inserted an O-ring seal.
5. A gun in accordance with claim 3 or claim 4 wherein said closure member is urged against said flange by an annular ring having a face parallel with that of said flange.
6. A gun in accordance with claim 5 wherein said ring is urged towards said flange by a plurality of screw clamps engaging said ring and said flange.
7. A gun in accordance with claim 5 wherein said ring is urged against said flange by hydraulic means.
8. A gun in accordance with claim 5 wherein said ring and said flange are in screw-threaded engagement with one another.
9. A gun in accordance with any one of the preceding claims comprising a clamping ring urging said one closure member against a flange on the end of said barrel, a collar extending from said clamping ring away from said barrel, a further ring slidably mounted in said collar, pin and slot means in said further ring and collar producing axial movement of said further ring in response to rotational movement thereof, said disrupting means being carried by said further ring.
10. A gun in accordance with claim 9 and including an actuator arranged to produce rotational movement of said further ring.
11. A gun in accordance with claim 10 wherein said actuator is a solenoid.
12. A gun in accordance with any one of preceding claims provided with a separator comprising a plate pierced by an aperture aligned with said barrel but of less diameter.
13. A gun in accordance with any one of the preceding claims when used with a projectile member consisting of a sabot containing a missile to be projected.
14. A gun in accordance with any one of claims 1 to 11 wherein the projectile to be discharged by said gun is connected with a recording device by way of an electrical conductor contained within said barrel and of length exceeding that of said barrel.
15. A gun in accordance with any one of claims 1 to 11 when used to project a projectile including a radio transmitter.
16. A gun in accordance with any one of claims 1 to 11 together with a receiver tube positioned to accept a projectile discharged from said barrel, said receiver tube being closed at the end thereof remote from said gun.
17. A gun in accordance with claim 16 wherein said receiver tube has a flange used to clamp said other closure member to a flange on said gun.
18. A gun in accordance with claim 15 or 16 wherein a restricted air outlet is provided in said closed end of said receiver tube.
19. A gun substantially as herein described with reference to the drawings.

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